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WSTIAC

WEAPON SYSTEMS TECHNOLOGY INFORMATION ANALYSIS CENTER

The Lobster Robot

by Joseph Ayers, Northeastern University
Joel L Davis, Cognitive and Neural Systems, ONR

Legged animals have adapted to a broad variety of underwater and land habitats. The ability to climb, breach, burrow and swim has evolved into groups as diverse as crabs, insects, spiders, mammals and humans and has been shown to share common underlying control mechanisms [1]. As a result, simple animal models such as insects and crustaceans provide proven solutions to the problems of navigation, searching and sensing in the most difficult of environments. Much desired robotic behavior has precise analogies in the behavior of animals.

One strategy for mine clearance in the littoral region is to use large numbers of relatively inexpensive robots, which crawl around on the bottom in a semi-random fashion[2]. In principle, the set of behaviors that a crab or lobster uses when searching for food is exactly what one would want a robot to perform when searching for underwater mines. The near-shore region of the ocean presents a challenging environment for such a work effort. Heavy turbulence caused by surge, wave action, tides and currents causes severe stability problems and limits the range of required sensors because of bubbles and particulates. Moreover, the requirement of locating both projecting as well as buried mines requires highly adaptable sensors. These problems have been overcome by bottom-dwelling legged organisms such as crabs and lobsters, which live with impunity in these complex conditions. Their ambulatory locomotory movements, combined with hydrodynamic adaptability, are a proven solution to the stability problem posed by this environment and provide performance advantages unavailable with more conventional vehicles [3].

1 Pearson, K.G. The control of walking. Scientific American 235 (1976), 72-86.

2 Gage, D. 1995 Many Robot MCM Search Systems. In Autonomous Vehicles in Mine Countermeasures Symposium, pp. 23-32. Monterey, CA.

3 Aponick, T. & Bernstein, C. 2003 Countermine operations in very shallow water and surf zone: the role of bottom crawlers. In Oceans 2003, vol. 4, pp. 1931-1940.

Contents

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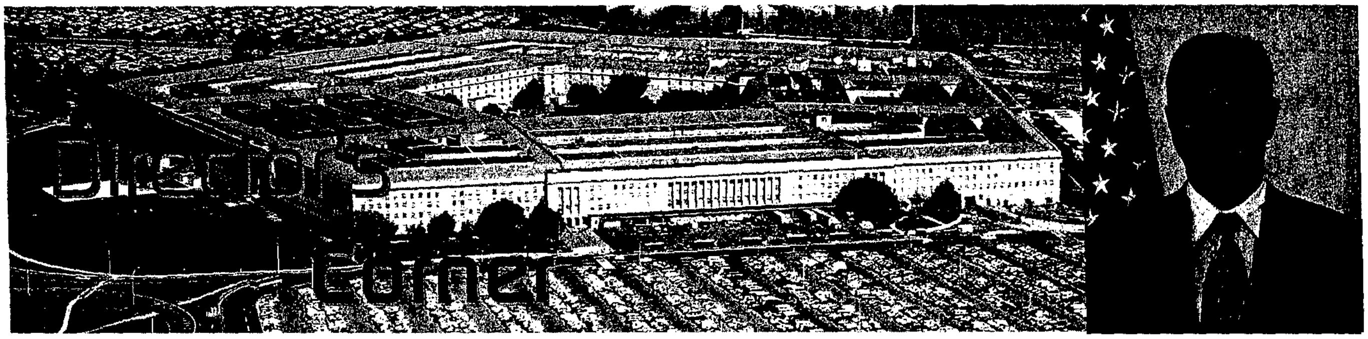

by Mr. Gary J. Gray

Ladies and Gentlemen:

We are pleased to present two articles that are both parts of a continuing series. The first article on biomimetics is written jointly by Dr Joe Ayers of Northeastern University in Boston, Massachusetts, and Dr Joel Davis of the Office of Naval Research in Arlington, Virginia. The other article is the second in a series on Systems Engineering by Rick Dean, Alion Science and Technology, Systems Division, Director for Systems Engineering and a member of the WSTIAC staff.

In the biomimetics article, Drs. Ayers and Davis describe a robot designed to emulate the mechanics of a lobster for potential littoral zone mine countermeasure applications. They describe the ambulatory locomotory movements and the hydrodynamic adaptability of a lobster and the manner in which they have implemented these abilities in the robot. They give a brief description of the biomimetic control architecture, the design of leg state machinery and its fabrication, and the biomimetic sensors, which allow the robot to navigate and perform autonomously in an unpredictable environment.

The second article discusses the relevance of systems engineering to DoD systems, and briefly touches upon the Essential Elements of Project and Systems Engineering, as described by Dr. Howard Eisner. We show how Systems Engineering can help to contain cost. We also suggest benefits and provide examples of using Systems Engineering in the Science and Technology phases of development to aid the transition into the acquisition phases, ultimately resulting in more successful DoD programs.

As always, I would appreciate any insights or comments you may have regarding these articles or topics you want addressed in our newsletter. I welcome guest authors that contribute to our mission. Please send any correspondence to gjgray@alionscience.com or call me at 703 933 3317.

Thanks,

Gary

The WSTIAC Newsletter is the current awareness publication of the Weapon Systems Technology Information Analysis Center (WSTIAC). WSTIAC, a Department of Defense (DoD) Information Analysis Center (IAC), is administratively managed by the Defense Technical Information Center (DTIC) under the DoD IAC Program.

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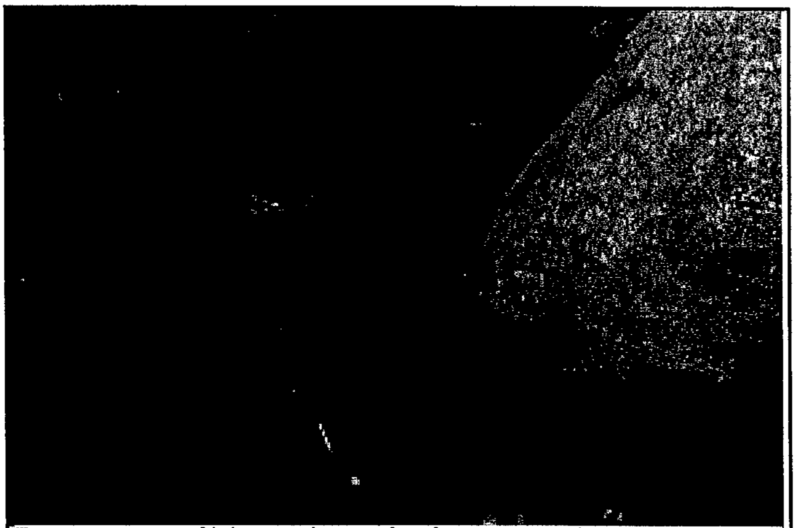
Lobster Robots (Continued from page 1)

When compared to terrestrial arthropods, underwater walking arthropods such as the lobster face a set of unique challenges[4]. First, lobsters must deal with a variety of often-complex bottom types such as sand, cobble, rock fields or eel grass beds. Dealing with obstacles in the environment requires high maneuverability, and lobsters have the ability to change their walking direction on a step-by-step basis. Rapid rotations in place are mediated by walking forward on one side and backward on the other. Rotation is enhanced by close placement of legs on the thorax. During walking, lobsters can yaw by walking more rapidly on one side relative to the other and/or differences in amplitude of movements on the two sides or a combination of these mechanisms.



Two generations of lobster Robots. Left, infinite power/infinite bandwidth version. Right. Autonomous version.
Courtesy John Williams, Office of Naval Research

A hydrodynamically adaptable shape can hold a lobster-based robot to the bottom rather than allowing current surge to displace it. Lobsters and crayfish use their claws, abdomen and swimmerets as hydrodynamic control surfaces and thrusters affording considerable adaptation relative to hydrodynamic perturbation during locomotion. Furthermore, their ability to walk adaptively in any direction allows them to preserve these hydrodynamic advantages like a wind vane while participating in a search procedure on an arbitrary heading. An ambulatory robot solves the stability problems of floating vehicles. It is continuously in mechanical contact with the sea floor, so it can pan and scroll through postural changes and thereby stabilizes sensors.

At Northeastern University, we have implemented a biomimetic robot based on the lobster. The robot features a finite-state machine controller, based on the prevailing biological model of how the nervous system generates locomotory movements: the Command neuron, Coordinating neuron, CPG architecture (CCCPG). The leg controller treats the CCCPG model components as objects that pass messages with regard to status changes. Since the controller communicates with the interface boards using a serial bus, the robot can be operated from an external laptop computer or from an embedded controller. Changes in walking direction, speed, load, etc., are effected by keystrokes on the laptop during development, or by sensor input or sonar supervisory commands to the embedded processor during autonomous operation.

At the single limb control level, the ambulation controller relies on three major classes of components to control the three joints of the limb. The oscillator component is a software clock that regulates the period of stepping as well as the duration of the swing or elevator phase fraction of the stepping cycle. The second major component of the ambulation controller is the *pattern generator*. It determines the pattern of discharge of bifunctional synergies based on command input and specifies the walking direction. The third major component of the ambulation controller is the *recruiter* that controls the strength of the muscular contractions. The outputs of the finite state machine are control signals that specify the timing and amplitude of artificial muscle contractions. These signals are used to gate power transistors at different duty cycles to activate contractions of the artificial muscle just as motor neuron action potentials activate muscle. Antagonist muscles of joints that serve a postural function in a particular walking direction are co-activated at low amplitude to increase the stiffness of the joint.

[4] Ayers, J. 2004 Underwater walking. Arthropod Structure & Development 33, 347-360.

Lobster Robots (Continued from page 3)

The leg-state machines gate current drivers that actuate antagonistic shape memory alloy (SMA) artificial muscles to move the different leg joints. The SMA actuators are formed from nitinol wire. When cooled by the surrounding seawater, the wires can be deformed and stretched to a martensite structure. When heated to the transition temperature by electrical current, the martensite converts to a more compact structure (austenite) and the wire contracts by about 5% from its deformed martensite length. A 250μ wire can lift a kilogram in about 150msec. Pairs of SMA actuators can produce alternating contractions or can be co-activated to maintain the stiffness of the joint. Pulse-width duty-cycle modulation of trains of current pulses allows graded contractions to regulate the attitude and speed of movements. Each actuator can be activated with three different duty cycles to produce low, medium and high amplitude contractions corresponding to the recruitment states of the controller.

The robot consists of an 8" by 5" hull actuated by eight three-degree-of-freedom legs and stabilized by anterior and posterior hydrodynamic control surfaces. The watertight hull contains the motherboard, leg-current driver boards, motor-controller board, sonar board and current drivers for the trim appendages. The motherboard houses power management circuitry, a compass and pitch and roll inclinometers. Eight modular walking-leg assemblies are attached to a flange on the hull. Each leg assembly is composed of vertical posts that contain muscle modules that protract and retract the leg around a capstan that supports the more distal joints. Two other segments house paired antagonistic actuators that cause elevation/depression and extension/flexion. Leg segments house springs that prevent overstress of the nitinol actuators and some measure of compliance. Watertight feed-throughs allow leg assemblies to be changed out in minutes. A separate battery compartment contains the nickel metal-hydride battery packs.

Anterior and posterior hydrodynamic control surfaces analogous to the claws and abdomen of the lobster are controlled in pitch by DC motors operating through jackscrew assemblies. A pair of antennae can be positioned at one of four yaw orientations or can be swept between any of the four positions by a separate DC motor/gear arrangement.

We have developed several biomimetic sensors necessary to mediate reactive tactile navigation on the ocean bottom. All sensors code information with a labeled line code. Each sensor is represented by a byte, each bit of which corresponds to a labeled line. The output of the analog sensors is processed and discreetized by a microcontroller. For example, the output of the antennal strain gauges is discreetized into 7 bits representing three different degrees of bending in the two directions and an eighth bit representing the rapid bidirectional bend associated with buckling in response to a head on collision. During operation, the state machine controller polls the sensor interfaces at variable rates appropriate to the context of the ongoing operation. The labeled line code represents three characteristics of the stimulus: (1) The sensory modality (tilt, antenna bending, etc), (2) the receptive field or orientation relative to the body and (3) the amplitude of the stimulus. All sensors return a byte representing their status. This byte is compared to masks representing different releasers. The current version of the lobster robot is equipped with an exteroceptive sensor suite that includes: (1) a compass to provide sense of direction pitch, (2) roll inclinometers to sense orientation in the pitch-and-roll plane, (3) antennae function as multidimensional sensors that respond to collision, active sweeps and water current and (4) bump detectors that respond to collisions by particular appendages such as the claws.

These sensors can trigger modulatory actions or behavioral sequences from the behavioral libraries. Adaptive behavioral sequences involve components that mediate responses to these contingencies that have been described in detail elsewhere[5]. For example, changes in pitch will evoke a reflex that levels the thorax. More complex, linked sequences involve lists of both fixed- and goal-achieving subsequences. Goal-achieving subsequences maintain ongoing states until a goal is achieved (e.g., turning to a particular compass heading). Achievement of the goal triggers the next subsequence in the list.

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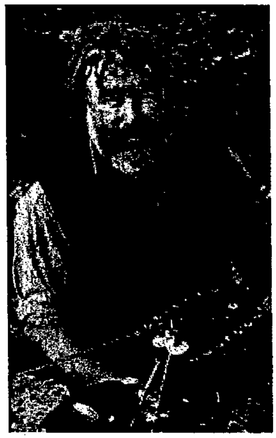
5 Ayers, J. 2002 A conservative biomimetic control architecture for autonomous underwater robots. In Neurotechnology for Biomimetic Robots (ed. J. Ayers, Davis, J. and Rudolph, A), pp. 234-252. Cambridge, MA: MIT Press. Ayers, J. 2004 Architectures for Adaptive Behavior in Biomimetic Underwater Robots. In Bio-mechanisms of Swimming and Flying (ed. N. Kato, Ayers, J., Morikawa, H.), pp. 171-187. Tokyo: Springer-Verlag.

The lobster robot can deploy a variety of mission packages. For example, a micromodem would allow long-baseline navigation and with an imager could be used to transmit images to an operator for identification purposes[6]. An ultra short-baseline sonar could mediate homing on sonar beacons, perhaps placed by marine mammals. A sensor for the chemical signatures of ordnance[7] would allow the vehicle to employ the odor-tracking behavior of lobsters to find and identify underwater mines. A key feature is the ability of the vehicle to deploy the imager and chemical sensor near the object of interest. ◆

6 Freitag, L. M. Johnson, M. Grund, S. Singh & J. Preisig. Integrated acoustic communication and navigation for multiple UUVs. Oceans 2001 4: 2065 - 2070

7 Kusterbeck, A. W., Deschamps, J. R. & Charles, P. T. 2005 Biosensor for underwater chemical sensing. In Photonics for Port and Harbor Security, vol. 5780, pp. 39. Orlando, FL, USA: SPIE.

About the Authors



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fyi....

Publications of interest

Effects of Nuclear Earth-Penetrator and Other Weapons

Committee on the Effects of Nuclear Earth-Penetrator and Other Weapons, National Research Council, 146 pages, 2005

Underground facilities are used extensively by many nations to conceal and protect strategic military functions and weapons stockpiles. Because of their depth and hardened status, however, many of these strategic hard and deeply buried targets could only be put at risk by conventional or nuclear earth penetrating weapons (EPW). Recently, an engineering feasibility study, the robust nuclear earth penetrator program, was started by DOE and DOD to determine if a more effective EPW could be designed using major components of existing nuclear weapons. This activity has created some controversy about, among other things, the level of collateral damage that would ensue if such a weapon were used. To help clarify this issue, the Congress, in P.L. 107-314, directed the Secretary of Defense to request from the NRC a study of the anticipated health and environmental effects of nuclear earth-penetrators and other weapons and the effect of both conventional and nuclear weapons against the storage of biological and chemical weapons. This report provides the results of those analyses. Based on detailed numerical calculations, the report presents a series of findings comparing the effectiveness and expected collateral damage of nuclear EPW and surface nuclear weapons under a variety of conditions. http://www.nap.edu/catalog/11282.html. ◆

Systems Engineering (Part II)

Why We Use It and What Are The Essential Elements

Richard Dean
WSTIAC

Welcome back. The previous issue dealt with the history of systems engineering and operations research. The larger problems discussed led to a systematic definition of an overall process or collection of processes. In particular, we touched upon three efforts addressed during World War II, and some of the personalities involved. In this issue, we'll cover why systems engineering is relevant and discuss the elements of systems engineering.

In the previous article, we briefly discussed why systems engineering is being emphasized in defense acquisitions by stating that Department of Defense Directive 5000.1 required it. The Department of Defense made this a requirement for several reasons. First, adherence to sound SE principles helps prevent cost overruns, since cost overruns occur every year. Secondly, a sound engineering approach helps prevent total system failures long before the test and evaluation phase, a point at which most of the appropriated money has been spent and alternatives are no longer feasible.

DoD Weapons Systems cost increases have been a major concern for many years. Pursuant to 10 USC §2432, Major Defense Acquisition Program (MDAP) costs must be reported to Congress in the form of Selected Acquisition Reports(SAR). All costs throughout the life cycle of the program are reported and include: Research, Development, Test and Evaluation (RDT&E), Procurement, Military Construction (MILCON), Operations and Maintenance (O&M) and Military Personnel. Only RDT&E, Procurement and MILCON are included in the net cost increase calculations.

For the December 2004 reporting period (the latest available for all MDAPs), there was a net cost increase of $59.6 billion (then-year (inflated) dollars) or +4.2% for programs that had reported previously. The net cost increase was due primarily to additional engineering changes (hardware/software) (+$35.2 billion), the application of higher escalation rates (+$32.1 billion) and a net stretch-out of development and procurement schedules (+$20.1 billion). The net increases were partially offset by a net decrease of planned quantities to be purchased (-$24.4 billion) and lower program cost estimates (-$6.6 billion).

While still a large dollar amount, the FY2004 SAR report was considered a success when measuring unit cost increases. During this period, there were no Nunn-McCurdy unit cost breaches that required notification (15% increase) or certification (25% increase).

Clearly, practicing sound systems engineering would not have prevented higher escalation but could have contributed to lower program cost estimates. The connection between systems engineering and the other effects on cost are less clear. As you will see later in the article, systems engineering also addresses O&M and Personnel, which represent a substantial portion of program life-cycle cost. The December 2004 SAR report provides some evidence that DoD's emphasis on systems engineering is providing some benefit in containing cost. The sheer volume of dollars involved as well as the complexity of the systems dictate that we continue down the systems engineering path while continuing to track metrics to prove the case.

The Nunn-McCurdy Amendment of 1982 addressed cost overruns in an attempt to control defense spending. This amendment called for the reporting of acquisition programs that experienced an increase of 15% or more in the current estimate of the program acquisition unit cost or average procurement unit cost in base-year dollars, a six-month or greater delay in the current estimate of any scheduled milestone since the current estimate of the previous report, or a milestone and an associated baseline approval within the last ninety days. Additionally, any program that experienced an increase of 25% or more required certification that it was vital to national security to prevent cancellation.

According to the FY2000 Annual Report of the Director of Operational Test and Evaluation, of fourteen systems beyond low-rate initial production, two were not operationally effective, and seven were not operationally suitable. In the same report, it was noted that the Defense Science Board had reported that in 2000, 80% of defense systems brought to operational test failed to achieve even half of their reliability requirement. The report also noted that OT results appear to be a factor of two to four times worse than those from Developmental Test (DT) and, in some cases, OT results are more than a factor of ten worse than DT. Finally, as systems become more and more complex, interwoven with other systems with regard to form, fit, and function, the challenges of managing such systems of systems become so intricate that it is difficult to imagine doing otherwise.

This leads to the question of why SE should be used in the Science and Technology community. Systems engineering, during the S&T phase, could help ease the transition to the acquisition phase, providing common terminology, concepts, and management techniques. It increases the probability of successful transition to an acquisition phase, giving the S&T community readiness to answer the hard questions that the acquisition community will put to them, and that will enable the S&T community to demonstrate successfully the proof of principles they have established.

Systems Engineering cont.

In fact, some principles and techniques of systems engineering, even though they may not be identified as such, are already in use within the S&T community. For example, the robotic lobster mentioned in this newsletter has had some level of systems engineering in its design. A mechanical leg has to functionally mimic that of a lobster. It must move up and down, in and out, and forward and backward, and it must do combinations of these basic motions. The mechanical leg is a systems engineering design, implementation, and developmental test effort to achieve these requirements. The robotic lobster must mimic the collective functions of a lobster's legs. The robot must also mimic the brain functions that allow the independent control of each of the eight legs allowing complex motion imitating the behaviors of an actual lobster. The mimicked brain functions involve the interface design and control of individual mechanical devices, such as legs, along with sensors, such as antennae, to provide the necessary inputs and mechanical outputs to achieve the required complex behaviors. There is an iterative design, implementation, and developmental test effort to confirm the prototype proof of principle.

To better understand systems engineering and its beneficial contribution to DoD weapons systems, we will turn to Dr. Howard Eisner and his description in Essentials of Project and Systems Engineering Management. He lists what he refers to as the "Thirty Elements of Systems Engineering."

These are:
(1) Needs/Goals/Objectives - This is largely a paperwork drill to insure that they are current and appropriately stated. Technique - Brute Force.
(2) Mission Engineering - This determines whether to upgrade a current system, develop a new system, or to do something else. Technique - (a) verification that a system has legitimate missions not carried out by other systems, and (b) providing a technical basis for full definition of system requirements. Brute Force again, perhaps by the development of a matrix.
(3) Requirements Analysis/Allocation - Technique - tearing a requirement down to sub-requirements, sort of like tearing a car apart. The development of matrices is highly recommended, and some tools exist to help facilitate this, i.e. DOORS.
(4) Functional Analysis/Allocation - Technique - looking at the requirements as developed in requirements analysis/allocation and determining the functions they perform. This is more matrix work using the same tools and techniques.
(5) Architecture Design/Synthesis - Technique - formulating a variety of alternative system architectures and analyses of those postulated architectures to verify that they satisfy the system requirements. Tools are useful in this process, and the selection of a specific tool depends on the individual attributes of the system under consideration.
(6) Alternatives Analysis/Evaluation - Technique - development of matrices and performance of trade studies to determine best alternatives for those postulated architectures that survived scrutiny in the previous element. Some tools are available, but standard office software will suffice.
(7) Technical Performance Measurement (TPM) - Techniques and Tools - this element involves detailed mathematical calculations relying heavily on both deterministic and stochastic methods. The use of tools, spreadsheets for example, are preferred over brute force techniques. The calculations determine if the required metrics can be met.
(8) Life-Cycle Costing (LCC) - Tools - this is a metric that never goes away. Analyses to determine what something will cost now, ten years from now, and throughout its useful life are necessary.
(9) Risk Analysis - involves the use of Tools, as calculations of consequences and probabilities can be complicated. Risk management, on the other hand, uses the technique of analyzing data generated by the analysis tools to manage risk according to whether it is a cost risk, a schedule risk, a technical performance risk, or some combination of the three.
(10) Concurrent Engineering - Technique - there are two basic ideas expressed as concurrent engineering. One is the continuous inclusion of developers and stakeholders in an engineering process from concept to disposal, and the other is the development of the integrated product team as the vehicle to achieve the integration of all life-cycle processes.
(11) Specification Development - Technique - this tends to be a brute force process of turning a design that satisfies developed requirements into formal documentation, and drafting diagrams that lay out the system and those processes, procedures, and products that support it.
(12) Hardware/Software/Human Engineering - Tools and Techniques - this element determines issues like the use of COTS (commercial-off-the-shelf), buy or build decisions, the lay-out that provides ease of use for operators and maintainers, whether a system uses software or firmware, and generally how the specification developed is executed.
(13) Interface Control - Tools and Techniques - this element generates descriptions and diagrams that specify all interfaces, be they functional, physical, electrical, electronic, mechanical, hydraulic, pneumatic, optical, or software.
(14) Computer Tool Evaluation and Utilization - Tools - this element involves computer-aided software engineering tools and/or software engineering environments. A subset of this would be software configuration management tools, which would or could also be a subset of the configuration management element listed below.
(15) Technical Data Management - Tools - the development of complex systems invariably means the develop-

ment of large volumes of technical data, which must be stored, organized, and managed. Data base management systems (DBMS) are required to accomplish this element.

(16) Integrated Logistics Support (ILS) - Tools - as a rule, over 50% of the life-cycle cost of a system is logistic in nature. This element is not essential within the S&T community, except for those working on the development of ILS support systems.

(17) Reliability, Maintainability, Availability (RMA) - Tools and Techniques - this element relies heavily on stochastic mathematics. A design that gives good consideration to this element can help reduce life-cycle costs and simplify an ILS system.

(18) Integration - Technique - this element involves the execution of one or more of the previous elements. Smaller units, called configuration items, are brought together to form larger units so they can be tested to assure they are operating correctly. Some items may be simulated as though they actually existed in order to test a system or subsystem, and some items may be stimulated to determine their behavior as though they were operating in an all-up system or subsystem.

(19) Test and Evaluation - Technique - this element nearly always involves the use of a Test and Evaluation Master Plan (TEMP). Test and evaluation is generally of two types, developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). DT&E is testing to determine whether a system works when put into operational mode (do the lights come on). OT&E is testing to determine whether a system satisfies the operational requirements as originally specified (do the headlights shine as far as they are supposed to).

(20) Quality Assurance and Management - Tools and Techniques - this element addresses the ability to insure that system parts meet specifications so that they are easily replaceable, can be continuously improved, and can be produced with greater ease, in less time, and at lower cost. This is an element that relies on stochastic mathematics. Examples of tools or methods are statistical process control and quality function deployment.

(21) Configuration Management - Tools and Techniques - this element is a bookkeeping and control activity that facilitates management of the development of a system and all of its subsystems. It is a way of keeping track by identifying an item, controlling what it looks like and how it is used, giving an audit of changes to the item, giving an account of its status (in a change process, in a test process, approved for use, etc.), and giving a traceability or history of its design, fabrication, etc.

(22) Specialty Engineering - Techniques - this element covers a wide spectrum of issues. It may involve electronic environmental effects (E3), low observable technology (reduced thermal signature, reduced radar signature, etc.), reduced operational health and safety hazards, reduced environmental impacts. Technical domains may include network engineering, aerodynamics, thermal analysis, structural analysis, hypersonics, nuclear engineering, or artificial intelligence, to name a few.

(23) Preplanned Product Improvement (P3I) - Technique - some systems may be needed before the completion of the longest lead item. Traditionally, turbine engines are an extremely long lead item. The military may have a requirement for a vehicle for which an engine has yet to be developed, so the vehicle can be designed to use an existing engine with provisions to incorporate the new engine as it becomes available. Training devices are an example of P3I procurements.

(24) Training - Techniques - this element reduces cost and risk in the life cycle process. First, the use of training devices generally means the actual system the device represents will usually have a longer operational life, and second, the cost of using training systems is generally less than training on the actual operational system. The use of training systems also allows for training in situations that would be too hazardous to perform in an operational system. A simulated engine failure would always be preferred in a simulator than in an actual aircraft.

(25) Documentation - Tools and Techniques - this element involves the use of word processors and drawing stations. It provides for an automated environment to archive the development of an entire system, on paper and/or electronically.

(26) Production - Tools and Techniques - this element encompasses the manufacturing processes. It addresses the quality and quantity of raw materials, storage of raw materials, storage of finished parts and products, methods of preparation for shipping, methods of shipping, lay-out of shop floors, and many other issues familiar to industrial engineers.

(27) Installation - Tools and Techniques - this element describes planned step-by-step strategy, methodology and timeline. It may be part of a plan for the arrival of an installation team that shows up on-site with fifty-pound toolboxes or the turn-in of a vehicle to a refit facility.

(28) Operations & Maintenance (O&M) - Tools and Techniques - this element involves the development of operational procedures and manuals, as well as maintenance procedures and manuals. It is an ongoing effort to provide operators and maintainers with the necessities to sustain the system. It can involve the development of new tools, techniques, and calibration methods and devices.

(29) Operations Evaluation/Reengineering - Tools and Techniques - this element involves maintaining a database or knowledge base of system performance over a long period of time. It provides the opportunity to identify specific areas that might be improved. The reevaluation of those specific areas of possible improvement is sometimes referred to as business process reengineering. The improvements may be the redesign of hardware and/or software, or it may be an alteration in the procedures of how the system is operated or maintained.

(30) Systems Engineering Management (Planning, Organizing, Directing, and Monitoring) - this element is the most important of all, as it involves the sound management of all previous elements mentioned above.

That which allows us to accomplish our goals by satisfying these elements, we have defined as tools and techniques. These are the things that allow the adoption of new paradigms, with some being simple and some being complex. Some involve the use of organizational skills and generic products used outside the realm of engineering, and some involve the use of specialized items designed specifically for engineering jobs. Also, some tools highly automate some techniques, and most techniques involve the use of one or more tools.

Summary

Systems engineering is important to the acquisition and the science and technology communities. It has been demonstrated that its use helps prevent cost overruns, helps prevent system failures, makes the development of extremely complex systems manageable, and ensures the warfighter gets the systems needed to perform the mission. The thirty elements of systems engineering, as outlined by Dr Howard Eisner, have been discussed in some detail and linked to the use of the tools and techniques of systems engineering.

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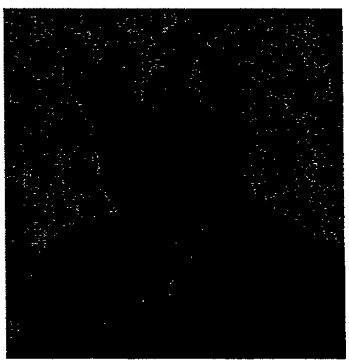
About the Author:



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in the news...

Tunnel 9 completes HCV testing

The Arnold Engineering Development Center's Tunnel 9 facility in White Oak, Md. is playing a crucial role in the ongoing Falcon program, with the completion of mission-critical testing of the Hypersonic Technology Vehicle 1.

The Falcon initiative is a joint Defense Advanced Research Projects Agency and Air Force program. The objective is to develop and demonstrate hypersonic technologies that will enable the capability to execute prompt global reach missions.

The ultimate capability is envisioned to entail a reusable Hypersonic Cruise Vehicle capable of delivering 12,000 pounds of payload a distance of 9,000 nautical miles in less than two hours.

The technologies required by an HCV include high lift-to-drag technologies, high temperature materials, thermal protection systems, and guidance, navigation and control. A series of hypersonic technology vehicles are planned to incrementally demonstrate these required technologies in flight.

Tunnel 9 alone provided the match of test conditions and data accuracy needed to make the program successful, according to Dan Marren, Tunnel 9 site director.

The Air Force Research Laboratory Air Vehicles Directorate at Wright-Patterson Air Force Base, Ohio, provides technical guidance for the Falcon program to DARPA.

During program technical reviews, AFRL suggested that the program could be enhanced by the inclusion of data from AEDC Hypervelocity Wind Tunnel 9.

"The Tunnel 9 facility exactly duplicates the HTV-1 flight Reynolds number at Mach 10, and the large model size permits accurate flow field resolution...Tunnel 9 will provide the best quality data and the best return on the investment of test dollars and effort," said Dr. Peter Erbland, the AFRL Air Vehicles scientific advisor.

More than 30 runs were successfully completed during this HTV-1 entry in AEDC Tunnel 9 at Mach 10 and 14. This data will help validate the aerodynamic data base at two important flight points prior to the upcoming critical design review.

According to DARPA officials, the joint program's goal is to develop and validate in-flight technologies that enable both a near-term (2010) and far-term (2025) capability to execute time-critical, prompt global-reach missions, while at the same time demonstrating affordable and responsive space lift.

by Philip Lorenz III, Arnold Engineering Development Center

NRL demonstrates fuel cell powered unmanned aerial system

The Naval Research Laboratory, in collaboration with industrial partners, demonstrated an unmanned aerial system (UAS) flight solely powered by fuel cell technology. The flight of the 5.6-pound 'Spider-Lion" lasted 3 hours, 19 minutes and consumed 15-grams of compressed hydrogen gas.

The project is a joint venture between NRL's Chemistry and Tactical Electronic Warfare Divisions and Protonex Technology Corporation. The flight was conducted with L3-BAI Aerosystems at their Ragged Island facility on Maryland's Eastern Shore under weather conditions of 65°F, moderate winds, and light rain at takeoff.

The 100-watt fuel cell system was designed and constructed at NRL largely using commercially available hardware and a fuel cell stack and components developed by Protonex. The "Spider-Lion" UAS was developed by NRL as a high-impact research platform for testing fuel cell technology. Research and development continues aimed at developing a fuel cell system capable of powering small military platforms currently in the field or in advanced development stages requiring extended operation that is not achievable using current battery technology.
NRL Press Release 11/29/2005

Sea-Based Missile Defense "Hit-To-Kill" Intercept Achieved

Air Force Lieutenant General Henry "Trey Obering, Missile Defense Agency Director, announced the completion of a successful Aegis Ballistic Missile Defense "hit-to-kill" intercept flight test conducted jointly with the U.S. Navy off the coast of Kauai in Hawaii. The test involved for the first time a separating target, meaning that the target warhead separated from its booster rocket. This was the sixth successful intercept test in seven flight tests conducted since intercept tests began in 2002. Previous tests were against unitary (nonseparating) targets representative of SCUD-type ballistic missiles.

The event, designated as Flight Test Maritime 04-2 (FTM 04-2), tested the Aegis Ballistic Missile Defense system. The Aegis program is the maritime component of the overall Ballistic Missile Defense System and is designed to intercept and destroy short- to intermediate-range ballistic missiles. The interceptor missile was launched from the Pearl Harbor-based Aegis cruiser USS Lake Erie (CG 70), using the operational version of Aegis Ballistic Missile Defense's Block 2004 configuration, which includes the Standard Missile-3 (SM-3) Block I missile.

At approximately 8:12 a.m. Hawaii Standard Time (1:12 p.m. Eastern Standard Time), a medium-range separating target was launched from the Pacific Missile Range Facility (PMRF), Barking Sands, Kauai, Hawaii. The USS Lake Erie (CG 70), outfitted with the Aegis Ballistic Missile Defense 3.0 Weapon System, detected, tracked the target and developed a fire control solution. Approximately four minutes later, the USS LAKE ERIE's crew fired the SM-3, and six minutes later the interceptor missile successfully intercepted the target warhead more than 100 miles in space above the Pacific Ocean and 375 miles northwest of Kauai. The intercept used "hit-to-kill" technology, which means that the target warhead was destroyed when the interceptor missile collided directly with the target.

The Aegis destroyer USS HOPPER (DDG 70), outfitted with the Aegis Ballistic Missile Defense equipment, was stationed off the coast of Kauai supporting the mission by performing long-range missile surveillance and tracking functions.

MDA and the U.S. Navy cooperatively manage the Aegis BMD Program. Navy Rear Admiral Kathleen Paige, who will retire from active duty in the near future, serves as the MDA program director. Lockheed Martin Maritime Systems and Sensors of Moorestown, New Jersey, is the Combat System Engineering Agent (CSEA) and prime contractor for the Aegis Weapon System and Vertical Launch System installed in Aegis-equipped cruisers and destroyers. Raytheon Missile Systems of Tucson, Arizona, is the prime contractor for the SM-3 missile and all previous variants of Standard Missile.

Contact Cheryl Irwin, Office of the Secretary of Defense, Public Affairs, at (703) 697-5331.

news... cont

Long' Distances Measured with Picometer Accuracy

A new laser-based method for measuring millimeter distances more accurately than ever before—with an uncertainty of 10 picometers (trillionths of a meter)—has been developed and demonstrated by a physicist at the National Institute of Standards and Technology (NIST). This is akin to measuring the distance from New York to Los Angeles with an uncertainty of just 1 millimeter. The technique may have applications in nanotechnology, remote sensing and industries such as semiconductor fabrication.

Laser light is typically used to measure distances by counting the number of wavelengths (the distance between successive peaks of the wave pattern) of light between two points. Because the wavelength is very short (633 nanometers for the red light most often used), the method is intrinsically very precise. Modern problems in nanotechnology and device fabrication, however, require uncertainty far below 633 nm.

A more precise method, described in the December 2005 issue of the Journal of the Optical Society of America A, involves measuring the frequency of laser light rather than the wavelength. The laser light is stored between two highly reflective mirrors, to create the optical analog of an organ pipe. The length of an organ pipe can be measured by driving the pipe with sound waves of a known frequency (pitch). The sound emitted by the pipe is loudest when it is driven at one of its natural frequencies, commonly called harmonics. When one or more of these frequencies is identified, the pipe length can be determined. In the NIST work, light is transmitted through both mirrors only when the frequency of the light matches a harmonic frequency. This frequency can be used to determine the distance between the mirrors.

While this approach has been used previously for the measurement of short distances (of the order of 1 micrometer), the new work extends it 25,000-fold by demonstrating a range of 25 millimeters. (Ultimately, the design should accommodate a range of up to 50 mm.) In addition, the NIST approach described in the paper excites two harmonics of the optical system, rather than one, a redundancy that increases the range while achieving picometer accuracy.

National Institute of Standards and Technology
Contact: Laura Ost, laura.ost@nist.gov, (301) 975-4034

Increased Precision Searches of Federal Science Database

The latest version of Science.gov was launched allowing more refined queries for searches of federal science databases. While Science.gov 3.0 is available to everyone, these improvements will be especially helpful to scientists and information specialists. Science.gov is the gateway to reliable science and technology information from 17 organizations within 12 federal science agencies. A single query searches across 30 databases and 1,800 Web sites. Science.gov allows users to search the surface Web as well as the deep Web, where traditional search engines cannot go. The information is free and no registration is required. Science.gov is hosted by DOE's Office of Scientific and Technical Information.

http://www.science.gov/
Contact: J. Sherwood (DOE), 202/586-5806 ◆

Directed Energy Weapons Course

Instructor: Dr. Edward Scannell, WSTIAC

Location: Huntsville, Alabama
14 to 16 March 2006

Course Description:

This one-day classified short course provides an introduction to the basic principles and techniques of Directed Energy Weapons (DEWs). The technologies behind each type of DEW will be examined, and the critical path components will be identified and explored with respect to their effect on future DEW development. In addition, advantages that can be achieved by employing DEWs will be discussed, as well as the status of U.S. and foreign DE developments and deployments. The key DEW programs in High Energy Lasers and RF-DEWs or High Power Microwaves will be fully described.

This short course will be of great benefit to people who need to understand the basic concepts, technologies, design requirements and practical applications of DEWs, including program and business managers, political decision makers, engineers, scientific researchers and military personnel. An undergraduate technical degree is recommended. Mathematics is kept to a minimum, but important formulas are introduced.

Questions to be examined include:

- What is Directed Energy and what are the different types of Directed Energy Weapons?
- What are the advantages and disadvantages of each type of DEW and what are their target effects and tactical and strategic capabilities?
- How do DEWs work and what are the critical technologies that must be developed for their eventual use in practical systems?
- How may threat DEW effects be countered and how can we protect our own systems?
- What are the major U.S. and international DEW programs that are being pursued?
- What is the prognosis for future DEW development?

About the Instructor:

Dr. Edward Scannell is the Senior Program Manager of the Engineering & Technical Division, Chief Scientist for WSTIAC, and formerly Chief of the Directed Energy and Power Generation Division of the U.S. Army Research Laboratory. He has 30 years of experience in technical areas related to DEWs, including: plasma physics; conventional and alternative energy sources, electromagnetic (EM) guns, particle beam, laser, high power microwave (HPM), and pulse power physics.

Security Classification:

The information presented is kept at the unclassified level, but is designated export controlled and limited to U.S. citizens only. The security classification of this course is UNCLASSIFIED.

Training at Your Location:

WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:

$700.00 for government personnel; $800.00 for government contractors.

Handout Material:

Each student will receive a comprehensive set of course notes covering the material presented.

For additional information, contact:
Mrs. Kelly Hopkins, Seminar Administrator,
at (256) 382-4747, or by e-mail
khopkins@alionscience.com

Notice: WSTIAC reserves the right to cancel and/or change the course schedule and/or instructor for any reason. In the event of a schedule change or cancellation, registered participants will be individually informed.

Introduction to Sensors and Seekers for Smart Munitions and Weapons Course

Instructor: Mr Paul Kisatsky, WSTIAC

Location: Huntsville, Alabama
TBD

Course Description:
This 3-day short course provides an introduction to the most commonly used sensors and seekers employed in smart munitions and weapons (projectiles, missiles and wide area mines). It is oriented to managers, engineers, and scientists who are engaged in smart weapons program development and who desire to obtain a deeper understanding of the sensors they must deal with, but who do not need to personally design or analyze them in depth. An undergraduate technical degree is recommended. Mathematics is kept to a minimum, but important formulas are introduced. This course also provides an excellent foundation for those scientists and engineers who desire to pursue this discipline to intermediate and advanced levels.

The course covers:

- Classification of seekers and sensors
- Fundamentals of waves and propagation
- Fundamentals of noise and clutter
- Fundamentals of search footprints
- Introduction to infrared
- Introduction to radar
- Introduction to ladar
- Introduction to visionics
- Introduction to acoustics
- Future projections and interactive brainstorming

Noise and clutter, the predominant obstacles to success in autonomous seekers, are given emphasis. The major sensor types are classified and each is discussed. In particular, infrared, radar, optical laser radar (ladar), imaging and non-imaging, and acoustic sensors are individually covered. Of special interest is the discussion on human visionics versus machine recognition, since this concept is of central importance to understanding autonomous versus man-in-the-loop sensing systems. The implications of "artificial intelligence", "data fusion", and "multi-mode" sensors are also briefly discussed. System constraints, which force tradeoffs in sensor design and in ultimate performance, are also covered. Time permitting, a projection of future trends in the role of sensors for smart munitions will be presented, followed by a "brain-storming" session to solicit student views.

About the Instructor:
Mr. Paul Kisatsky is a Senior Physical Scientist. He is a nationally recognized expert on sensors and seekers for smart munitions and weapons and has more than 30 years of hands-on experience developing sensors and seekers fielded in modern smart munitions and weapons.

Security Classification:
This course is unclassified.

Training at Your Location:
WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:
The registration fee for this 3-day course is $950 for U.S. government personnel and $1150 for government contractors. Contractor teams of 3 or more, registered at the same time, are charged $950 per person.

Handout Material:
Each student will receive a comprehensive set of course notes covering the material presented.

For additional information, contact:
Mrs. Kelly Hopkins, Seminar Administrator,
at (256) 382-4747, or by e-mail
khopkins@alionscience.com

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Weaponeering Course

Instructor: Professor Morris Driels, US Naval Postgraduate School

Location: Huntsville, Alabama
28 February to 2 March 2006

Course Description:

This 2½-day short course is based on a very successful graduate-level weaponeering course developed by Professor Driels and taught at the Naval Postgraduate School(NPS), Monterey, CA. The course will provide an overview of the fundamentals of the weaponeering process and its application to air-to-surface and surface-to-surface engagements. The course explains the analytical basis of current weaponeering tools known as the Joint Munitions Effectiveness Manuals (JMEMs) produced by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). The JMEMs are used by all Services to plan offensive missions and allow the planners to predict the effectiveness of selected weapon systems against a variety of targets.

The short course is divided into three parts.

Part I covers the basic tools and methods used in weaponeering:

- The weaponeering process
- Elementary statistical methods
- Weapon trajectory
- Delivery accuracy of guided and unguided munitions
- Target vulnerability assessment

Part II covers the weaponeering process for air-launched weapons against ground targets:

- Single weapons directed against point and area targets
- Stick deliveries (point and area targets)
- Projectiles (guns and rockets)
- Cluster munitions
- Weaponeering for specific targets: bridges, buildings, etc.)
- Collateral damage modeling

Part III covers the weaponeering process for ground engagements:

- Indirect fire systems - artillery and mortars.
- Direct fire systems - infantry and armored vehicles.
- Mines - land and sea.

About the Instructor:

Professor Driels is a Professor of Mechanical Engineering at the U.S. Naval Postgraduate School in Monterey, California. He has worked with the JTCG/ME on a variety of topics in support of the JMEMs for a number of years. He has taught a quarter-long weaponeering course at NPS for three years and he has published a textbook on the subject.

Security Classification:

The security classification of this course is UNCLASSIFIED.

Training at Your Location:

WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:

The registration fee for this 2½-day course is $950 for U.S. government personnel and $1150 for government contractors. Contractor teams of 3 or more, registered at the same time, are charged $950 per person.

Handout Material:

Each student will receive a comprehensive set of course notes covering the material presented.

For additional information, contact:
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at (256) 382-4747, or by e-mail
khopkins@alionscience.com

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Smart/Precision Weapons Course

Instructors: Mr. Hunter Chockley and Mr. Mark Scott, WSTIAC

Location: Huntsville, Alabama

28 to 30 March 2006

Course Description:

This 2½-day short course provides a comprehensive understanding of smart weapons and related technologies. This course is aimed at providing general knowledge about smart weapons technology and a source of current information on selected U.S. and foreign smart weapons, to include system description, concept of employment, performance characteristics, effectiveness and program status.

A variety of ground, sea and air smart/precision weapon systems are discussed, to include fielded and/or developmental U.S. systems such as Joint Direct Attack Munition (JDAM), Joint Air-to-Surface Standoff Missile (JASSM), Small Diameter Bomb, Javelin, Line-of-Sight Anti-Tank (LOSAT), XM982 Excalibur, Extended Range Guided Munition (ERGM), Common Missile, Tomahawk, Standoff Land Attack Missile - Expanded Response (SLAM-ER), Cluster Bomb Munitions and Airborne Laser, among others, as well as representative foreign smart/precision weapons.

The objective of this course is to inform materiel and combat developers, systems analysts, scientists, engineers, managers and business developers about smart/precision weapons, to include:

- State-of-the-art of representative U.S. and foreign smart weapons systems;
- Employment concepts
- Smart weapons related systems, subsystems, and technologies; and
- Technology trends.

About the Instructors:

Mr. Mark Scott and Mr. Hunter Chockley are Science Advisors. Each instructor has more than 25 years of experience with weapons technology and/or smart/precision weapons.

Security Classification:

The information presented is kept at the unclassified level, but is designated FOR OFFICIAL USE ONLY (FOUO), export controlled, and attendance is limited to U.S. citizens. The security classification of this course is UNCLASSIFIED.

Training at Your Location:

WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:

The registration fee for this 2½-day course is $950 for U.S. government personnel and $1150 for government contractors. Contractor teams of 3 or more, registered at the same time, are charged $950 per person.

Handout Material:

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Calendar of Events

Upcoming Conferences and Courses

January 2006

11-13 January 2006
Aviation Symposium and Exhibition
Washington, D.C.
For additional information:
http://www.ausa.org/webpub/DeptIndustry.nsf/byid/DeptIndustry.nsfhome

18-20 January 2006
ION National Technical Metting 2006
Monterey, CA
For additional information:
http://www.ion.org/meetings/meetings.cfm#ntm

21-26 January 2006
Photonics West 2006
San Jose, CA
For additional information:
http://spie.org/conferences/programs/06/pw/

24 January 2006
Joint Improvised Explosive Device Defeat Conference
Washington, DC
For additional information, Email: cbuck@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1OF0YTIML&MID=6070

24-25 January 2006
Tactical Power Sources Summit
Washington, DC
For additional information:
http://www.idga.org/cgi-bin/templates/genevent.html?topic=329&event=8638&

24-26 January 2006
Defending America/SpaceComm 2006 Symposium
Colorado Springs CO
For additional information:
Anne Marshall 719.635.7558 amarshall@isiscompany.net
Jim Hazuka at 719.554.1062 james.hazuka@northcom.mil.
http://www.rockymtn-afcea.org

24-26 January 2006
TechNet Orlando 2006
Orlando, FL
For additional information: http://www.afcea-orlando.org

31 January - 2 February 2006
AIAA Strategic and Tactical Missile Systems Conference
Monterey, CA
For additional information:
http://www.aiaa.org/content.cfm?pageid=230&lumeetingid=1182

February 2006

5-7 February 2006
2006 Tactical Wheeled Vehicles Conference
Monterey, CA
For additional information, Email: adekleine@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1OF0YTIML&MID=6530

7-9 February 2006
Munitions Executive Summit
Phoenix, AZ
For additional information, Email: pedmonson@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1OF0YTIML&MID=6650

7-9 February 2006
AUVSI's Unmanned Systems Program Review 2006
Washington, DC
For additional information:
http://www.auvsi.org/programreview/?sub=prog&subnav=home_index

15-17 February 2006
AUSA Winter Symposium
Ft. Lauderdale, FL
For additional information:
http://www.ausa.org/webpub/DeptIndustry.nsf/byid/DeptIndustry.nsfhome

28 February - 2 March 2006
Joint Integrated Air & Missile Defense Summit 2006
Huntsville, AL
For additional information:
http://www.jiamdsummit.org

March 2006

6-9 March 2006
22nd Annual Test & Evaluation Conference
Jacksonville, FL
For additional information, Email: ebrown@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1OF0YTIML&MID=6910

13-15 March 2006
Special Operations/Low Intensity Conflict Conference & Exhibition
Arlington, VA
For additional information, Email: cohara@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1OF0YTIML&MID=6880

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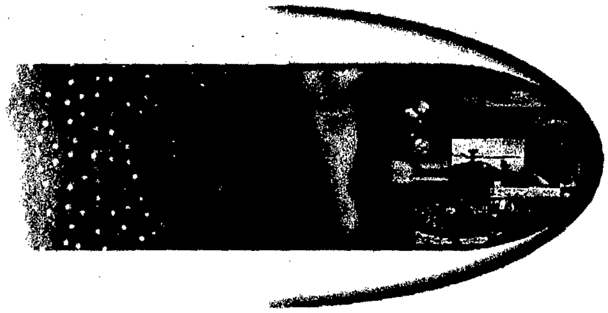

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